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SELECTED TECHNICAL SPIN-OFFS
FROM THE SPACE PROGRAM

PROFESSIONAL STUDY

No. 4130 By Herman L. Gilmore

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AIR UNIVERSITY
UNITED STATES AIR FORCE
MAXWELL AIR FORCE BASE, ALABAMA

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A RESEARCH REPORT SUBMITTED TO THE FACULTY

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ABSTAINER

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AIR WAR COLLEGE RESEARCH REPORT SUMMARY

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TITLE: Selected Technical Spin-offs from the Space Program

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The author discusses some of the problems which the National Aeronautics and Space Administration has encountered in getting people to understand how the general public has profited from the technical discoveries of the space program. Next, he describes NASA's Technology Utilization Program and comments on it. He then describes some of the many spin-offs from the space program; these include examples from management technology, communications, aeronautics, medicine, fabrics, highway safety, and weather forecasting.

SELECTED TECHNICAL SPIN-OFFS FROM THE SPACE PROGRAM

Scientific and engineering accomplishments of this nation's space program are well known to any interested observer or reader. It is true that a vast amount of new technology has been discovered and much emphasis has been placed on it and the possibility of its use in the non-aerospace community. Even so, Dr. Wernher von Braun stated recently in an article discussing why space is essential to man's future: "We have reached out, but somehow have not been able in all cases to grasp and identify with the man on the street."[1]

Why is this so? Why does this man on the street ask when approached on this subject: "What practical benefits to mankind are being produced by this country's space program?" Is this not the same good citizen who stayed awake until all hours of the night with his eyes glued to his television (comprised of printed circuit boards, transistors, diodes, etc.) marvelling at coverage of the many space spectaculars. It is quite obvious that he does not realize that the basic purpose of science, research, and advanced technology is one of long term gain.

President John F. Kennedy was well aware of the time required for such an immense project when he proclaimed in 1961 that the goal of this nation's space program was to land a man on the moon and return him safely to Earth by 1970. When compared to the period of time from the day that Benjamin Franklin flew his famous kite until man began to enjoy the benefits of electricity, the infant space age has been revolutionary in producing useful spin-offs.

If such a small investment as a kite and key could give returns in the billions of dollars, then it might be assumed that a similar multiplication factor would hold true in time for the space endeavor.

Congressman Olin E. Teague of Texas made the following statement when he was asked why we should spend so much money on space instead of on Earth problems:

> Well, there was plenty to be done in Europe when Columbus left it. And there is still plenty to be done there. If Columbus had waited until Europe had no more internal problems, he would still be waiting, but the opening up of the new world did more to revive European culture and economy than any internal actions could possibly have done.[2]

Dr. Edward Teller, nuclear physicist and professor at the University of California remarked similarly to the question of space expenditures: "When Columbus took off, the purpose of the trip was to improve trade relations with China. That problem has not yet been solved to this very day, but just look at the byproducts."[3]

It is true that a considerable amount of money has been spent on this program and that some of the knowledge acquired has no apparent immediate applicability to practical use, however, a great deal of the knowledge is transferrable immediately to practical use. This paper intends to illustrate how some of the innumerable technical spin-offs have affected not only the citizens of this country but the rest of the world as well.

Transfer of Technology

Mr. Hubert H. Humphrey, while he was Vice President of the United States, made the following comment:

> Out of this great investment of money and intellectual energy we have harvested not only an acceleration of national productivity and services, not only a sweeping advance in scientific and technological accomplishment, but also many new materials, products and processes that have already begun to enrich our lives. In many cases these might still be far in the future were it not for the yeasty activity of the Space Age.[4]

Yes, the technological developments demanded by the vigorous space program have already resulted in many useful transfers or spin-offs. Much credit for the dissemination of information pertaining to technical developments and spin-offs must be given to the National Aeronautics and Space Administration's Technology Utilization Program. The purpose of this program has been to inform industrial, medical, and educational communities of such useful

technological innovations resulting from NASA's research and development programs. Many of these by-products have important technological and economic applications in a wide variety of often unrelated activities.

From the monumental effort exerted by NASA and its contractors to create an entirely new order of technology, a vast computerized library of know-how was accrued. NASA's Technology Utilization Office is actively promoting the widest possible use of this information by continually screening the new technology and issuing reports on the transferable items. A flow of new products and processes into the civilian economy is a major yield of NASA's computerized storehouse of knowledge which houses over 750,000 technical reports which are constantly being updated. In 1969, NASA handled almost 10,000 requests for detailed technical support packages compiled by the Technology Utilization Office.[5]

Several hundred technical innovations generated yearly in the space program find their way into our technology where they lead to improved kitchen appliances and farm equipment, better sewing machines, radios and television sets, better airplanes and ships, more efficient weather forecasting and storm warning, better communications, better medical instruments, and better tools for everyday life.

Management Technology

NASA and its contractors had to develop and put forth an extraordinary management effort to meet the demands of the goals and timetables set for the space program. As did their scientific and engineering counterparts, management personnel had to develop an entirely new order of capability because traditional methods were not sufficient. These improved methods are presently being utilized by various industries and by different levels of government to promote improved commerce and to help solve some of the nation's pressing social problems.

The City of Los Angeles, for example, recently awarded a one-year contract for study of the city's overburdened services and to formulate plans for a command and contact system to provide rapid pinpointing of field forces, computer dispatching, computerized information files, automatic transmission and signaling for police vehicles, individual communications for hazardous duty personnel, and automatic status displays. The above contract was awarded as a direct result of the Los Angeles City Council's citing the experience and success of space management technology.[6]

Benefits to Communications

International television is probably the best known benefit from space research in the field of communications, however, the above

mentioned man on the street becomes accustomed to such innovations and quickly forgets its origin. Several years of extensive research and development were expended on communications satellites before international television became a reality. Without these satellites there could be no "live" watching in our living rooms of the Olympics in Europe and Mexico nor the opening of Expo '70 in Japan.

Even more important than our leisure enjoyment of global television is the potential of educating the millions of people in underdeveloped nations. For example, a joint United States-India project in mass instructional television is under development. The satellite to be used is an advanced satellite known as Applications Satellite "F" and will be available after the United States completes its planned purpose.

Unlike existing satellites where the signal must be received by a ground station and amplified for redistribution, this particular satellite is capable of broadcasting television images directly to small, special low-cost receivers. In 1972, the satellite will be maneuvered into a stationary orbit over India where it can broadcast to some 5,000 villages equipped with the special receivers built in India. From a few strategically located transmitting stations, the Indian Government will beam to the satellite educational programs

pertaining to population control, improvement of farming processes, etc. The satellites will inturn retransmit the signal to the many thousands of people in receiver equipped villages.[7] It takes very little imagination for one to realize the tremendous potential of such systems.

Dr. von Braun commented further in his article on space exploration:

> Before long we shall have a truly global communications system, an intricate nervous system for all mankind, which will eliminate barriers of time and distance, and render geographic and political barriers meaningless.
>
> The present type of home antennae could be modified at little expense to receive the ultrahigh frequency transmissions from extremely powerful, nuclear-powered synchronous satellites. Every isolated farm, mountain shack, or thatch-roofed hut could be linked with cultural centers.
>
> A home television set on the dirt floor of an isolated shack would reveal a better way of life, brush aside resistance to change and arouse determination for self-improvement.[8]

Although television affects the greatest number of people, it is not the primary benefit of the communications satellite. Only about 2 percent of the global Intelsat system's capacity is required by television. World commerce has been the greatest benefactor through the use of voice and message communications. The cheaper

and more reliable communications has immeasurably increased international business efficiency.

NASA's primary contribution to improved communications has been the satellite, but resulting benefits have evolved from the space program's need for fast landline data links and radio transmission. Industry has responded by developing better long distance cables and radio circuits. A direct spin-off from these improvements is the enjoyment by business and their customers of increased efficiency through wider and rapidly growing use of computer connected data transmission systems. Major banks have instantaneous coast-to-coast data networks, as do the airlines but for a different application. The latter being established to give rapid reservation service. There are numerous other applications today with many others to be augmented in the near future.

Aeronautics

One bonus to aeronautics from space research is in air navigation. The newest jet liners have an invaluable navigational aid using the same basic principle that the Apollo crewmen used to pinpoint their position in space.[9] The device is comprised of a computer fed by a series of accelerometers which sense every movement of the airplane. The computer receives the inputs from the accelerometers and translates the information into instantaneous and

continuous position reports. This equipment being more accurate than previous navigational aids contributes to shorter flight times and a saving in fuel.

NASA also conducts extensive aeronautical research separately from the space program. One such project deals with air pollution from airplane engines. Research has uncovered practical ways to reduce smoke by increasing the air intake in the engines and burning fuel at higher temperatures, thus decreasing the carbon monoxide and unburned hydrocarbons in the exhaust. Commercial airlines are presently installing smoke-reducing combustors on their engines.

Another aeronautical research problem led to solving the aircraft skidding problem encountered on wet runways. NASA found that "hydroplaning" was caused by a build-up of water film under tires moving at high speed.[10] The tires would lose contact with the pavement and skim the surface of the water layer like a hydroplane. The solution to the problem was grooved runways to break up the skid-promoting film.

Still another space program spin-off applicable to the aeronautical field, as well as others, is a small sending device called a "pinger" which was developed to help NASA locate space vehicles or equipment that had fallen into the ocean.[11] It is a directional system which is triggered when water closes the contact of the

battery powered onboard element. The device emits pings which can be detected by surface receivers, enabling rapid location of the submerged object.

One organization that is very interested in the device is the Federal Aviation Agency. They are considering including pingers in the automatic flight logs of transoceanic airplanes, so that in the event of a crash, the log can be recovered and the cause of the accident established.

The Department of Defense has already adapted the device for navigational markers, in aircraft, torpedoes, missile nose cones, and on underwater equipment and systems.

Benefits to Medicine

One of the prime recipients of technology transfer from space research has been the medical community. An enormous amount of intensive research was required in the field of bioscience and related equipment design to allow astronauts to live and perform tasks in the space environment. Breakthroughs and advances in the areas of microminiaturization, telemetry, and instrumentation have had a very favorable impact on medical systems.

It has been estimated that nearly two-thirds of the deaths resulting from heart attacks occur in less than an hour after the attack. In most cities and communities, because of traffic problems and

distances to the hospital, transit time in the ambulance is often lost time in terms of diagnosis and treatment. A recent innovation developed by NASA shows great promise in helping to alleviate this problem of delayed information. The system, originally designed to monitor pilots heart responses under strenuous flight conditions, is comprised of electrodes sprayed on the patients body so that heart actions in the form of signals can be radioed directly to the hospital from a moving ambulance.[12] This enables the doctor to read the electrocardiographic information from a console thus providing him with advanced knowledge of the patient's condition even before the ambulance arrives.

The technique for applying the above mentioned electrode consists of spraying a conductive mixture over the wire leads and the skin. A highly volatile solvent in the mixture provides quick drying, leaving a thin, flexible layer of conductive material that holds the lead wires firmly in contact with the skin. The excellent adherence and flexibility of the electrode arrangement enables the system to be used for recording the subject's heart action during exercise on a treadmill, bicycle ergometer, etc. When such tests have been completed, the electrodes can be removed easily.

A most recent invention, called a heart rate tachometer, was developed by two NASA electronic experts at the Marshall Space

Flight Center.[13] The tachometer is an electronic device designed to instantly measure heart rates of astronauts while they live and work in orbiting space stations. The unique feature of the invention is that an almost instantaneous rate is determined after only two heart beats are measured, as compared to other techniques which average the pulse over a period of time to obtain a rate. The device, controlled by electric impulses from the body, produces a heart rate signal by measuring the time separating two heart beats. Between 40 and 200 beats per minute can be measured by the system to an accuracy of less than one heart beat.

In this same general area of interest, research at NASA has evolved an automated patient monitoring system, which can help ease the pressing problem of hospital personnel shortage.[14] Packages containing medical instruments and a tiny radio transmitter, weighing only a few ounces, can be placed on a patient's wrist to monitor blood pressure, heart action, and body temperature. The radio permits free movement by the patient since no wires are attached. The central monitoring station can handle up to 64 patients simultaneously. A unique feature of the system is that the radioed information is coded in such a manner that it can be fed into a computer for instant correlation with the patient's medical history.

Fabric Spin-offs

The development of aluminized mylar, the material used for the Echo balloon satellites, has led to several everyday uses. A small emergency lightweight blanket made from this material is now on the market. The blanket weighs almost nothing, can be folded to handkerchief size, and is fairly inexpensive.

In a similar application, sportsmen now have available lightweight, aluminized, woven nylon men's wear, like the blanket above, capable of trapping up to 80 percent of the wearer's body heat. The process used was developed in the Apollo program where aluminum is vacuum deposited on the nylon substrate. A major sportswear company, which manufacturers these articles reports that the material has the highest insulation efficiency per pound of any known useable insulating material.

Aluminized mylar has been used also in industry to insulate transfer lines and storage containers for cryogens.

The tragedy of the Apollo capsule fire in early 1967, in which three astronauts lost their lives, led NASA to search for a family of materials that could be used safely in an oxygen environment. This search led to the development of fireproof textiles, foams, plastics, and paints that hold great promise for commercial and industrial use. For example, airlines are studying the use of these

materials to reduce the possibility of cabin fires. The Navy is experimenting with a NASA foam to protect aircraft fuel tanks from incendiary bullets.

Highway Safety

The Bureau of Public Roads recently tested a special shock absorber designed for use on Apollo spacecraft couches.[15] This special design was found to be capable of reducing a sixty mile per hour impact on a highway guard rail to the equivalent of five miles per hour. The shock absorber is relatively inexpensive, rugged, resetable, therefore reuseable. The automobile industry is attempting to design the device into automobile bumpers in some 1972 models. One insurance company has announced a collision premium reduction of about 20 percent for automobiles equipped with the device which consists essentially of an inner tube with O-rings around it fitting tightly into an outer tube. When compressed or extended, the rolling O-rings absorb considerable energy.

Another automotive related benefit is grooved highways for reducing skidding and related accidents. NASA's work on aircraft tire hydroplaning led to the grooving of airport runways and the same equipment is now being used on dangerous sections of highways in 18 states. Reported results indicate an 80 to 90 percent

reduction in damage, injury, and death from skid accidents in the previously reported high incident areas.

Weather Forecasting

Similar to the communications satellite, the weather satellite has been a great benefit to mankind. Early research led to the establishment of a weather satellite network under the Environmental Science Service Administration.[16] This network is composed of several camera equipped satellites with the cameras pointed toward the Earth to photograph and relay cloud coverage to Earth stations. The network has provided excellent information for short-range forecasts, but since cloud coverage alone is not sufficient to give long-range forecasts, further developments are needed and are being made. Recent advances in sensors capable of sensing other meteorlogical conditions from satellites in orbit give promise for increasing the forecast range. With the new sensors, weather satellites can now take infrared photographs of cloud coverage at night.

Hurricane Camille was detected far out in the Atlantic Ocean by a Nimbus satellite and was continually tracked with its path accurately plotted. About 70,000 people were evacuated from the gulf coast to safer places inland; many took refuge in the NASA

Mississippi Test Facility. Had it not been for the Nimbus satellite, it is estimated that as many as 50,000 people might have lost their lives.

The most recent major disaster, killing an estimated 500,000 people, occurred in mid-November, 1970, when a devastating cyclone struck the shores of East Pakistan. Had the previously mentioned communications satellite system with village receivers as planned for India and weather satellite information been available to East Pakistan, thousands of lives might have been saved.

More than fifty other countries do receive weather forecasts. These forecasts are based on cloud-cover photographs relayed from a space system equipped with NASA developed satellites. The development of simplified, compact, inexpensive receiving stations has made it possible for even the smallest nation to afford participation in the weather network.

Last year alone, 12 Atlantic hurricanes, 10 eastern Pacific hurricanes and 17 western Pacific typhoons were sighted, identified and tracked by meteorological satellites. This country has been able to catalog Pacific cloud and weather patterns since 1962, with data available only from weather satellites.

There has been much advancement in these satellites since their inception. Color television cloud pictures from NASA's

experimental Applications Technology Satellite in stationary orbit are now being received and used in near real time. Airline pilots at Kennedy Airport routinely receive a weather photograph of their planned transatlantic route.

In summary, this most productive space endeavor has produced a twofold effect on science and technology in general. Because the decision to explore space made immense demands on all fields of science, it led to numerous discoveries quite unrelated to space exploration. These unrelated dividends, present and future, affect practically every phase of human convenience and concern, and promise continuing and increasing return on the space investment for the benefit of mankind.

NOTES

1. Dr. Wernher von Braun, "Why Space Exploration Is Vital to Man's Future," Space World, Vol. F-9-69, September 1969, p. 31.

2. Remarks in the House of Representatives in May 1968.

3. For the Benefit of All Mankind, A Survey of Practical Returns from Space Investment. Report of the Committee on Science and Astronautics, US House of Representatives, 91st Congress, 2nd Session September 14, 1970, Washington, DC, p. 6. Hereafter cited as For the Benefit of All Mankind.

4. Hubert H. Humphrey, "Vitality of the National Space Program," TRW Space Log, a publication of TRW, Inc.

5. For the Benefit of All Mankind, p. 9.

6. Ibid., p. 11.

7. Ibid., p. 15.

8. von Braun, op. cit., p. 32.

9. For the Benefit of All Mankind, p. 16.

10. Aerospace Related Technology for Industry, A conference held at NASA Langley Research Center, Hampton, Va, May 22, 1969.

11. Space Program Benefits, Hearing Before the Committee on Aeronautical and Space Sciences, United States Senate, 91st Congress, Second Session, April 6, 1970, Washington, DC, p. 37. Hereafter cited as Space Program Benefits.

12. Medical Benefits from Space Research, a NASA publication, US Government Printing Office 1968-0-323-074.

13. NASA Marshall Space Flight Center press release to the Huntsville Times October 30, 1970.

14. Medical Benefits from Space Research, a NASA publication, US Government Printing Office 1968-0-323-074.

15. Space Program Benefits, p. 36.

16. Ibid., p. 17.